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Mining typical load profiles in buildings to support energy management in the smart city context

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Abstract

Mining typical load profiles in buildings to drive energy management strategies is a fundamental task to be addressed in a smart city environment. In this work, a general framework on load profiles characterisation in buildings based on the recent scientific literature is proposed. The process relies on the combination of different pattern recognition and classification algorithms in order to provide a robust insight of the energy usage patterns at different levels and at different scales (from single building to stock of buildings). Several implications related to energy profiling in buildings, including tariff design, demand side management and advanced energy diagnosis are discussed. Moreover, a robust methodology to mine typical energy patterns to support advanced energy diagnosis in buildings is introduced by analysing the monitored energy consumption of a cooling/heating mechanical room.

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Keywords: buiding energy management; building energy profiling; load profiles characterisation; typical energy patterns.

1. Introduction

The last decades have seen a profound transformation in the energy system of many countries worldwide. The progressive introduction of renewable energy sources in buildings in a smart city context and the consequent effort for decarbonisation have changed the way to use and manage energy. The improvement of building energy efficiency is a central theme both in scientific community and global political environment. Important opportunities to address

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this task are provided by the implementation of strategies aimed at enhancing the building energy management and operation. In this context the increasing implementation of Information and Communication Technologies (ICT) and Energy Management System (EMS) in buildings has enabled an easier availability of a huge amount of heterogeneous building related data making it possible a bi-directional communication between infrastructures and operators [1]. As a consequence, in the last few years, an increasing interest of researchers and energy companies in exploring the potentialities of data analytics procedures to extract information on the actual building energy behavior was observed [2–6]. The application of data analytics techniques coupled with a robust physics-based expertise can effectively support the implementation of procedures or strategies aimed at enhancing the operational performance of buildings [7]. In particular, the mining of time-series data has recently gained high attention in the scientific literature as a way to describe the load patterns and the boundary conditions (e.g., weather, time period or user/customer features) influencing their particular variation over time. The electrical or thermal load time series are usually characterised by a particular trend with stochastic components and time based cycle at annual, seasonal and daily scales [8].

In the process of load profiles characterisation, data driven recognition techniques play a key role for the identification of typical operational patterns and trends in a high-dimensional time series [9]. Pattern recognition procedures usually require time series to be segmented in a pre-processing step. In the analytical process of building load profiles, time series are usually chunked into subsequences through a fixed length window to obtain a time scale based profiles. In the majority of energy and buildings applications load profiles are usually well described on a daily scale. The mining of time based load profiles is an emergent task which enables the implementation of various energy management and diagnostic strategies at both single and multiple buildings/customers level. Load profiles can be analysed at different scales and/or at different levels of detail or for specific building energy services. The process of daily load profiling primarily consists in grouping similar load profiles using domain expert based procedures, statistical methods or data mining algorithms. For each group of similar load profiles a representative load pattern can be extracted. The shape of a load profile is usually representative of an operational pattern of a building/customer or a sub-system. It is intended as the daily-based set of time-related features defining that specific pattern under bounded load conditions. When time series sub-sequences are compared to discover similar shapes a data scaling is a task to carry out in order to isolate the effect of the magnitude and allow the data mining algorithms to perform correctly for this purpose. Clustering algorithms proved to be particularly effective in discovering robust energy patterns from time series data [9]. In the framework of energy profiling data mining techniques are commonly applied to classify energy consumers or to detect anomalous energy patterns or for the short-term forecasting according to customer/building and temporal variables. In fact, the mining of typical load patterns can be also viewed as a powerful pre-processing phase for the implementation of predictive models of building energy consumption [8]. For different typologies of users (e.g., industrial, residential, commercial) relevant differences could be observed in the daily energy profiles. Furthermore, for the same typology of users, various daily load profiles can be extracted usually depending by the weather, the day of the week, the season or specific features of the building/customer. Depending on whether a single or a group of buildings/customers are analysed, different implications arise from the process of load profiles characterisation. In the first case a detailed diagnostic analysis of energy time series is performed to discover interesting energy patterns characterising the operation of building/customer or sub-systems. In the second case, instead, the objective becomes a load classification to discover typical classes of buildings/customers according to profile shape similarity [10,11]. The process of typical load profiles recognition is beneficial for different actors in the smart city environment:

- An in-depth knowledge of building typical load profiles could help managers in developing different strategies involving energy savings opportunities related to the management of renewable energy systems [12] or thermal/electrical storage systems. Information on typical daily patterns may drive the design of targeted tariff plan or of proper demand side management (DSM) strategies [10,13]. Moreover, the energy mangers can benefit from load profiles characterisation for exploiting anomaly detection initiatives [3].
- Energy Service Companies (ESCO) acting as building managers could benefit from the knowledge of typical building load profiles to develop energy savings and conservation measures.
- Transmission System Operators (TSOs) and Distribution System Operators (DSOs) may both benefit from energy profiles identification for the management of theirs grids and markets. In the case of smart electricity grids or